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SOME RECENT PAPERS ON EARTHWORMS.

BY J. S. KINGSLEY.

THE Oligochaetous worms were long neglected, but within recent years the literature relating to them has extended to very considerable dimensions. It is the intention to present here an abstract of some of the work lately done on the group. The two papers¹ by Dr. Wilson on the embryology of these forms may be considered together. The forms studied are called *Lumbricus terrestris*, *L. communis*, and *L. foetidus*.

The segmentation is unequal, but varies in its details in individual eggs of the same species. It results in the formation of a blastula, in which, at intervals, the blastocœl is in communication with the exterior by a cleavage pore. Some points of difference are shown between the species studied and that which formed the basis of Kleinenberg's classic paper.

Like Kleinenberg, Dr. Wilson finds that the "primary mesoblasts" are differentiated before gastrulation as two large cells lying side by side, at first on the surface but later sinking into the blastocœl. Before this insinking they begin to bud off the mesoderm in the shape of two parallel rows of cells. During this process gastrulation takes place. The egg becomes flattened, and a differentiation of the cells of the two sides occurs, the upper

¹ Wilson, Edmund B. The Germ-Bands of *Lumbricus*. *Journal of Morphology*, I., p. 183, 1 pl., 1887.

—The Embryology of the Earthworm; *L. c.*, III., p. 387, 7 pls., 1889 [1890].

(ectodermal) becoming flattened, while the entodermal are larger and more columnar. Next the sides of this placula-like structure are bent downwards, the approaching edges forming the slit-like blastopore, which closes behind, leaving the anterior end open as the mouth. In this operation the primary mesoblasts lie side by side at the posterior lip of the blastopore, the bands extending forward and eventually uniting in front of the mouth. During this process the ectoderm becomes thickened immediately over each band, but retains its character of a layer a single cell in thickness. At the same time, although the blastopore never closes, the inpushing of a stomodæum occurs.

The next feature of interest is the formation of the middle layer of the germ-bands, the existence of which was first distinctly recognized in the *Oligochætes* by Dr. Wilson. According to his account, this first appears as a linear arrangement of the ectoderm² cells, terminating behind in a larger cell. These terminal cells (which, like the primary mesoblasts, are called teloblasts) sink, together with the corresponding cell-rows, into a position between the ectoderm and the germ-band proceeding from the mesoblast. There may be either three or four of these rows on either side. The one towards the median line gives rise to the nervous system, the next two (nephric rows) to the nephridia and to the inner series of setigerous glands, while the outer (not constant) has a problematical fate. The corresponding teloblasts are called neuroblast, nephroblast, and lateral teloblast.

With the gradual elongation of the embryo these teloblasts continue to bud off new cells, which add to the corresponding row, which derive nothing from any other source. Behind, the rows are but a cell in width, but anteriorly they are wider, the two nephric rows becoming fused. Later the teloblasts disappear, and the bands of the opposite sides unite from before backwards. Certain cells budded from the rows wander between ectoderm and entoderm and form "migratory mesoderm," while the remainder, in which the cœlomic cavities appear, is the "trunk mesoderm." The former is mesenchymal in character, and gives rise to larval muscles, which are later replaced by true mesothelial muscles. The

² See below for Bergh's account, which differs considerably.

cœlomic cavities are schizocœlia, and are formed in the mesodermal bands behind the point of concrescence; the most anterior pair lie at the sides of the stomodæum, while a head cavity, which is always unpaired, occurs in front of the mouth.

The first blood vessel to appear is the subintestinal. It is at first without proper walls, and is apparently a remnant of the cleavage cavity. The dorsal vessel is at first double.³ The two halves concresce from in front backwards.

Concerning the alimentary canal little need be said in this abstract. The stomodæum pushes inward as far as the sixth segment, and in one species its lips are at one time armed with a peculiar structure which may be either sensory or may serve as a larval digestive organ. As soon as the stomodæum is formed the larva begins to swallow the albumen with which it is surrounded and the particles of this are apparently swallowed amœba-like by the entoderm cells. The œsophagus with its calciferous glands is entodermal. The proctodæum is long delayed, and when it appears it is formed in the region where the primary mesoblasts break up; but our author was not able to decide whether in front or behind them, *i.e.*, within or without the limits of the blastopore.

The nervous system arises from the neural rows budded from the neuroblasts. The two most important statements made are: that the brain arises from these rows, and that it has a primitively paired condition and does not arise from a scheitelplatte. Dr. Wilson was unable to find any mittelstrang in the ventral cord. With growth the brain is carried backward from an extreme anterior position to the third somite, while by the same process the ganglia of the two anterior post-oral somites are pushed back upon that of the third to form the infracœsophageal ganglion. The giant fibres are apparently specially modified nerve fibres,—a view in conflict with Vejdovsky's account.

The origin of the excretory system as described by Wilson is quite different from the accounts of Bergh summarized farther on. First in the history comes the larval excretory organs or "schluckzellen," which are at first large ectoderm cells forming the anterior lip of the blastopore, and connected with a delicate system of

³ This condition is permanent in many earthworms belonging to the family Perichætidæ.

ciliated canals lying between ectoderm and entoderm. They soon disappear. These were not carefully studied, nor were the pronephridia or head-kidneys. The permanent nephridia are regarded by Wilson as arising partly from the nephric rows, which are, as we have seen above, ectodermal in origin, and comparable in every early ontogenetic feature with the neural rows; the funnel is regarded as derived from the mesoderm proper. According to the account and figures, the nephric rows send upgrowths into every somite; these join a large cell on the anterior wall of each dissepiment. The large cell develops the funnel, while the cells of the nephric upgrowth becomes perforated to form the tubular portion of the nephridium. From each nephridial anlage a process is developed which becomes hollow, and the setæ of the inner row are developed in the cavities thus formed.

The speculations with which Wilson concludes his paper are of extreme interest, but as they deal with problems of general morphology they may be omitted here.

R. S. Bergh has also studied the development of the earthworm, with especial reference to the nervous system and Wilson's germ-bands. His account⁴ differs in so many particulars that we cannot consider the fate of the germ-bands as settled.

Bergh paid no attention to the segmentation and gastrulation, but begins his account with the formation of the germ-bands. As his account of the fate of the different portions differs from Wilson's interpretation, he has applied different names to different portions, as is seen by this schedule:

WILSON.		BERGH.
Primary mesoblast	=	Posterior myoblast.
Neuroblast	=	Neuroblast.
Nephroblasts	} =	Anterior myoblasts.
Lateral teloblast		

In the earliest stage studied by Bergh there is present on either side the posterior myoblast, the neuroblast, and a single

⁴ Bergh, R. S. Neue Beiträge zur Embryologie der Anneliden. I. Zur Entwicklung und Differenzirung des Keimstreifens von Lumbricus. *Zeitschr. f. wiss. Zoologie*, Bd. L., p. 469, 3 pls., 1890.

one of the anterior myoblasts, each budding off its corresponding row. In next stage observed there were present two anterior myoblasts. The connection between these was not made out, but Bergh thinks from certain features that the new one was budded from the earlier one, and that the first to appear corresponds to Wilson's inner nephroblast, the second to his lateral teloblast. A later stage showed the budding off from the inner myoblast of the middle myoblast, and still later this was seen to form a row which becomes insinuated between the other rows. All of these cells are as yet ectodermal, and the neuroblasts and the neural rows are the first to become covered by the ectoderm. Apparently the bands are solely derived from the teloblasts, and the ectoderm contributes nothing further to this growth.

Bergh describes a new element in the nervous system as a plexus of nerve cells and nerve fibres, which develop along the middle of the ventral surface between the neural rows. In the ectoderm of this region, just beneath the ciliated line, are certain uni- and bipolar cells, the processes of which run lengthwise of the animal, and form a temporary nervous system before the permanent nervous system has begun the development of nerve fibres. These cells are regarded as arising independently of the neuroblasts from the ectoderm, the fact that they extend behind the neuroblasts being strongly confirmative of this view. Later this plexus is included in the permanent nervous system, while the ciliated cells are resorbed, and, contrary to Kleinenberg's view, do not form part of the regular ectoderm. Bergh suggests that the ventral median multipolar elements described by Friedländer may originate from this plexus. Hatschek's median invagination does not exist in *Lumbricus*.

The three remaining germ-bands, says Bergh, have nothing to do with the formation of the nephridia, and at no place do they project inwards, as described by Wilson, into the inner muscle plate. They rather spread out between ectoderm and the product of the hinder myoblast, and give rise to the circular muscles of the adult worm. These muscles are first formed ventrally, and later reach the dorsal surface.

The nephridia are, on the other hand, derived wholly from the inner mesoderm, the first portion to be distinguished being the

large funnel cells, which are recognizable before the formation of the coelomic cavities. With the formation of the coelom a row of cells buds off from the hinder surface of each dissepiment, just behind the funnel cell, to give origin to the tubular portion of the nephridium. The anterior myoblasts contribute nothing towards the formation of the nephridia, and these organs from the first have no structure uniting the successive somites. Bergh thinks that Wilson has misinterpreted his sections, and has missed some of the stages. The bristle sacs which Wilson thinks are derived from the germ-bands are, according to Bergh, formed as ingrowths from the ectoderm. With such differences of interpretation it, is difficult to say which is right. The work is in each case apparently thoroughly done, and a comparison of plates does not serve to reconcile the two accounts.

Benham's recent paper on the genera and species of earthworms⁵ will prove of great value to students of the group, and an abstract is given here in the hope that it may aid American students of the group. The forms occurring in the United States are scarcely known. The Oligochaetes are divided into:

NAIDOMORPHA.

Small worms of relatively few somites; blood uncolored; male genital pores in, or in front of, somite VII.; asexual and sexual reproduction; eye spots frequently present; embraces the families Aphanoneura, Naidæ, Chætogastridæ, and the genus Ctenodrilus.

LUMBRICOMORPHA.

Male genital pores behind somite VII.; reproduction only by sexual process; somites behind the peristomium all similar; no eye spots.

The characters separating the two divisions are not constant, except that which refers to the network of blood-vessels on the nephridia.

⁵ Benham, W. B. An Attempt to Classify Earthworms. *Quarterly Jour. Micros. Sci.*, XXXI., p. 201, 1890.

MICRODRILI (Water Worms).

No capillary network of blood-vessels on nephridia ; small size, thin, transparent body wall ; setæ always in four groups per somite ; prostomium not separated from peristomium by a groove. Contains families Discodrilidæ, Enchytræidæ, Phreoryctidæ, and Lumbriculidæ.

MEGADRILI (Earth Worms).

Large forms from one inch to six feet in length. Body wall thick and opaque ; prostomium (when present) separated from peristomium by a groove ; capillary network of blood-vessels on the nephridia ; clitellum always occupying more than two somites. These are divided into PLECTONEPHRICA, with the nephridia in the form of delicate tubules in each somite, uniting to form a network, with more or less numerous external apertures ; and MEGANEPHRICA, with the excretory network absent, replaced by a pair (rarely two pairs) of large nephridia in each somite. The members of each division are given below, the genera known to occur in the United States being given in italics .

PLECTONEPHRICA.

Family TYPHÆIDÆ ; genera Typhæus, Megascalides, Cryptodrilus, Didymogaster, Perissogaster, Dichogaster, Digaster.

Family ACANTHODRILIDÆ ; genera Acanthodrilus, Trigaster, Dinodrilus, Neodrilus, *Diplocardia*.

Family PERICHÆTIDÆ ; genus Perichæta (including Megascolex).

MEGANEPHRICA.

Family MONILIGASTRIDÆ ; genus Moniligaster.

Family EUDRILIDÆ ; genera Eudrilus, Teleudrilus, Pontodrilus, Photodrilus, Microscolex, Rhododrilus, *Plutellus*, Stuhlmannia, Hyperiodrilus.

Family PERIONYCHIDÆ ; genus Perionyx.

Family GEOSCOLECIDÆ ; genera Geoscolex, Urochæta, Diacheta.

Family RHINODRILIDÆ; genera *Rhinodrilus*, *Microchæta*, *Urobenus*, *Hormogaster*, *Brachydrilus*.

Family LUMBRICIDÆ; genera *Lumbricus*, *Allolobophora*, *Criodrilus*, *Allurus*.

Besides the above, Benham includes four genera of uncertain position, viz., *Helodrilus*, *Echinodrilus*, *Antæus*, and *Eisenia*.

The genera of Megadrili recognized by Benham may be separated by the following key, modified only in method of arrangement from that given by him :

A, Setæ 16 to 80, or more, in a ring.

α, Male pores far apart; small tufts of nephridia;

Perichæta.

αα, Male pores very close together; large nephridia;

Perionyx.

AA, Twelve setæ on somite; clitellum on somites 14-16;

Dinodrilus.

AAA, Eight setæ on somite.

α, Setæ alternate in consecutive somites throughout body; male pore on somite 22;

Diachæta.

αα, Setæ alternate only posteriorly; male pore 20-21;⁶ clitellum on somites 14-22;

Urochæta.

ααα, Setæ in rows, not alternating.

β, Male pores 10-11, or 11-12;

Moniligaster.

ββ, Male pores on somite 13;

Allurus.

βββ, Male pores on somite 15.

γ, Prostomium dovetailed completely into peristomium;

Lumbricus.

γγ, Dovetailed incompletely;

Allolobophora.

γγγ, Not dovetailed;

Criodrilus.

ββββ, Male pores 15-16;

Hormogaster.

βββββ, Male pores on somite 17.

γ, Clitellum on somites 14-17.

δ, Setæ separate;

Rhododrilus.

δδ, Setæ in couples.

ε, One pair of sperm sacs;

Typhæus.

⁶ Between somites 20 and 21.

- εε, Two pairs of sperm sacs; *Digaster*.
 rr, Clitellum on somites 14-18; setæ
 in couples; *Eudrilus*.
 rrr, Clitellum on somites 13-17;
 lobed prostates, one pair; *Microscolex*.
 rrrr, Clitellum on somites 13-20;
 prostates tubular, two pairs; *Dichogaster*.
 ββββββ, Male pores on somite 18.
 r, Two pairs of prostates on somites
 17-19.
 δ, Male pores in a deep fossa; *Trigaster*.
 δδ, Male pores not in a fossa; *Acanthodrilus*.
 rr, One pair of prostates on somite 18.
 δ, Clitellum on somites 13-17.
 ε, Prostomium dovetailed.
 ζ, Prostate convolu-
 ted; *Pontodrilus*.
 ζζ, Prostate lobate; *Cryptodrilus*.
 εε, Prostomium not dove-
 tailed; *Photodrilus*.
 δδ, Clitellum on somites (13)
 14-17; prostomium dove-
 tailed; setæ separate; *Plutellus*.
 δδδ, Clitellum on somites 14-18.
 ε, Setæ equidistant; *Didymogaster*.
 εε, Setæ in couples; *Perissogaster*.
 δδδδ, Clitellum on somites
 13-21 or more; *Megascolides*.
 rrr, No prostates; clitellum on
 somites 16-21; *Brachydrius*.
 βββββββ, Male pores 18-19.
 r, Prostomium broad; setæ simple;
 clitellum 15-23. *Geoscolex*.
 rr, Prostomium elongate; setæ or-
 namented; clitellum 15-25; *Rhinodrilus*.
 ββββββββ, Male pores on somite 19.
 r, Clitellum 10-25; *Microchæta*.

17, Clitellum 14-17;	<i>Teleudrilus.</i>
ββββββββββ, Male pores on somite 20;	
clitellum 14-25;	<i>Urobenus.</i>

In explanation of the above key it may be said that the peristomium is regarded as the first segment. The prostomium is sometimes separated from the first somite by a transverse groove; but frequently grooves start on the prostomium and extend back into the first somite, so that the prostomium appears "dovetailed" with the peristomium. If the grooves stop after traversing the first somite for a short distance, the prostomium is partially dovetailed. The external openings of the sperm ducts are the male pores. The term sperm sacs is applied to the vesiculæ seminales, the testes of the older authors; the prostates are diverticula of the sperm ducts near their external opening.

There are several genera which are not included in the above summary. Thus Garman has described⁷ a genus *Diplocardia*, from Illinois, which belongs to the family *Acanthodrilidæ*, but differs from *Acanthodrilus* in having the dorsal vessel paired throughout its entire length, and in the absence of a subneural blood-vessel. It agrees with *Dinodrilus* in the double dorsal vessel, but differs in having but eight setæ. Garman also mentions the existence of *Perichæta* in Champaign, Ill. A species, apparently of the same genus, occurs in Lafayette, Indiana, where it caused the students no little trouble to make it fit the description of *Lumbricus* given in Brooks's Zoology.

A paper by Michaelsen⁸ has not been seen. It describes several African forms of the family *Eudrilidæ*, among them a genus *Stuhlmannia*. Allied to is another African genus lately described by F. E. Beddard.⁹ It is called *Hyperiodrilus*, and presents many interesting peculiarities of reproductive organs.

⁷ Garman, H. On the Anatomy and Histology of a New Earthworm (*Diplocardia communis*). Bulletin Illinois State Laboratory of Natural History, III., pp. 47, 5 plates.

⁸ Jahrbuch der Hamburg wissensch. Anstalten, Bd. VII.

⁹ Beddard, F. E. Preliminary Note on a New Earthworm Belonging to the Family *Eudrilidæ*. *Zool. Anzeiger*, XII., 1890.

The genus *Deodrilus*¹⁰ proposed by Mr. Beddard has its sole representative in Ceylon. It seems to combine the character of several of Benham's families, and its exact position is uncertain. Beddard regards it as nearest *Typhæus* and the *Geoscolicidæ*, with some affinities with *Pontodrilus* and many *Eudrilidæ*. Beddard announces a forthcoming classification of the earth-worms.

In the same paper he describes a connection of the nephridia with the terminal region of the intestine as occurring in the New Zealand species *Acanthodrilus multiporus*. These nephridia are connected with the general nephridial network found in the *Pleconeprhica*. Whether the portion of the intestine with which they are connected is proctodeal or entodermic is unsettled. Beddard makes some interesting comparisons with the respiratory trees of the *Gephyrea chætifera*, and also with the malpighian tubes of the Hexapods.

THE MECHANICAL ORIGIN OF STRUCTURE IN PELECYPODS.

BY ROBERT TRACY JACKSON.

IT is desired in this paper on Pelecypods to call attention to some cases recently studied in which the structure of the animal seems to be the direct consequence of the physiological reaction induced by the mechanical requirements of the environment; or to cases of "mechanical genesis," as they have been termed.¹ Several of our examples are cases in which similar forms are built up on similar lines of development, but in widely separated or totally distinct groups of animals. They therefore afford evidence

¹⁰ On the Structure of a New Genus of *Oligochaeta* (*Deodrilus*); and On the Presence of Anal Nephridia in *Acanthodrilus*. *Quart. Jour. Mic. Sci.*, XXXI., p. 467, 2 pls., 1890.

¹ This paper is taken largely from a recently published memoir, to which the reader is referred for a fuller discussion of many facts presented. See *Phylogeny of the Pelecypoda, the Aviculidæ and Their Allies*; by Robert Tracy Jackson. *Mem. Bost. Soc. Nat. Hist.*, Vol. IV., No. 8, July, 1890, pp. 277-400, pls. XXIII.-XXX.